MM5130

DC to 26 GHz High Power RF Switch

RoHS COMPLIANT

Product Overview

Description

The MM5130 device is a high-power and wide frequency range SP4T micro-mechanical switch. Menlo Micro has developed a new Ideal Switch® fabrication process and applied it to DC and wideband RF/microwave switch applications. This innovative technology enables highly reliable switches capable of 25 W power handling. The MM5130 provides ultra-low insertion loss and superior linearity as an SP4T from DC to 18 GHz, and greater than 3 billion switching cycles.

The MM5130 can also be configured in Super-Port mode that extends the frequency operation to 26 GHz. The MM5130 is an ideal solution for replacing large RF electromechanical relays, as well as RF/microwave solid-state switches in applications where linearity and insertion loss are critical parameters. The four switch channels are individually controllable by applying a gate voltage to the corresponding RF GATE pin.

Features

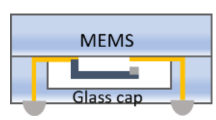
- DC to 26 GHz Frequency Range
- 25 W (CW), 150 W (Pulsed) Max Power Handling
- Low On-State Insertion Loss: 0.3 dB @ 6.0 GHz
- High Linearity, IIP3 95 dBm Typical
- 25 dB Isolation @ 6.0 GHz / 45 dB Super-Port Mode
- High Reliability > 3.0 x 10^9 Switching Operations
- 2.5 mm x 2.5 mm WLCSP Package

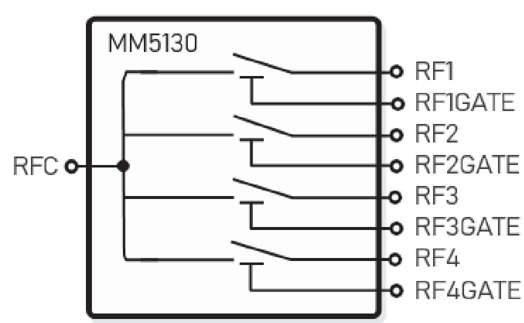
Markets

- Defense and Aerospace
- Medical Equipment
- Test and Measurement
- Wireless Infrastructure

Applications

- Switched Filter Banks and Tunable Filters
- High Power RF Front Ends
- Antenna Tuning
- Low-Loss Switch Matrices & EM Relay Replacement





  November 11, 2024 www.MenloMicro.com

Electrical Specifications

Operating Characteristics

Absolute Maximum Ratings

Exceeding the maximum ratings as listed in Table 1 below may reduce the reliability of the device or cause permanent damage. Operation of the MM5130 should be restricted to the limits indicated in Table 2.

Electrostatic Discharge (ESD) Safeguards

The MM5130 is a Class 0 ESD device. When handling the MM5130, observe precautions as with any other ESD sensitive device. Do not exceed the voltage ratings specified in Table 1.

Table 1. Absolute Maximum Ratings[1]

Parameter	Minimum	Maximum	Unit
Open State Voltage Rating / Switch RF1-4 to RFC[2]	-150	150	V
Open State Voltage RF1-RF4, RFC to GND, GATE pin to GND Potential[2 3]	-150	150	V
Closed State Voltage RFGATE Pins to RF1-RF4, RFC, GND[2]	-100	100	V
Hot Switching Voltage[4]	-0.5	0.5	V
DC Current Rating/Switch[5]	—	500	mA
Operating Temperature Range	-40	+85	ºC
Storage Temperature Range[6]	-65	+150	ºC
Mechanical Shock[7]	—	500	G
Vibration[8]	—	3.1	Grms

Notes:

1. All parameters must be within recommended operating conditions. Maximum DC and RF power can only be applied during the on-state condition (cold-switched condition).
2. This also applies to ESD events. This is a Class 0 device.
3. RF pins must not be allowed to electrically float during switch operation. See section Floating Node Restrictions for details on avoiding floating nodes.
4. See section Hot Switch Restrictions for more information.
5. Total current of all channels combined.
6. See section Storage and Shelf Life more information on shelf and floor life.
7. See JESD22-B104 for mechanical shock test methodology at 1.0ms, half-sine, 5 shocks/axis, 6 axis.
8. See JESD22-B103 for vibration test methodology at 3.1G and 30min/cycle, 1 cycle/axis, 3 axis.

Electrical Characteristics

All specifications valid over full supply voltage and operating temperature range unless otherwise noted.

Table 2. DC and AC Electrical Specifications

Parameter	Minimum	Typical	Maximum	Unit
Operating Frequency Range				
Normal SP4T mode	DC	—	18	GHz
Super-Port Mode	DC	—	26	GHz
CW Power @ 6 GHz[1]	—	—	25	W
Peak Power @ 6 GHz[2]	—	—	150	W
Insertion Loss				
Normal SP4T mode @ 6 GHz	—	0.3	—	dB
Super-Port mode @ 6 GHz	—	0.3	—	dB
Normal SP4T mode @ 18 GHz	—	1.3	—	dB
Super-Port mode @ 18 GHz	—	0.8	—	dB
Normal SP4T mode @ 26 GHz	—	—	—	dB
Super-Port mode @ 26 GHz[3]	—	1.0	—	dB
Input/Output Return Loss				
Normal SP4T mode @ 6 GHz	—	15	—	dB
Super-Port mode @ 6 GHz	—	15	—	dB
Normal SP4T mode @ 18 GHz	—	10	—	dB
Super-Port mode @ 18 GHz	—	18	—	dB
Normal SP4T mode @ 26 GHz	—	—	—	dB
Super-Port mode @ 26 GHz[3]	—	20	—	dB
Isolation				
Normal SP4T mode @ 6 GHz	—	25	—	dB
Super-Port mode @ 6 GHz	—	45	—	dB
Normal SP4T mode @ 18 GHz	—	18	—	dB
Super-Port mode @ 18 GHz	—	32	—	dB
Normal SP4T mode @ 26 GHz	—	—	—	dB
Super-Port mode @ 26 GHz[3]	—	22	—	dB
Channel to Channel Isolation @ 6 GHz	—	25	—	dB
Third-Order Intercept Point (IP3)[4]	—	95	—	dBm
Second Harmonic (H2)[5]	—	-130	—	dBc
Third Harmonic (H3)[6]	—	-130	—	dBc

Parameter	Minimum	Typical	Maximum	Unit
On/Off Switching and Settling Time				
Turn on time[7]	—	8.5	16	µs
Turn off time	—	2.5	6	µs
Full Cycle Frequency	—	—	10	kHz
On/Off Switch Operations[8] (MM5130-03NDB)				
at 25 ºC	3×10^9	30×10^9	—	Cycles
at 70 ºC	—	1×10^9	—	Cycles
at 85 ºC	—	0.1×10^9	—	Cycles
DC Steady State Carry Current	—		500	mA
Off-State RFC to RFOUT Leakage Current[9]	—	15	150	nA
On-State Resistance (R_{ON})	—	1.2	3	Ω
Off-State Capacitance (C_{OFF})	—	15	—	fF
Video Feedthrough[10]	—	16	—	mV_{Peak}
Gate Bias Voltage (V_{BB})	87	89	91	V_{DC}
Gate Voltage Slew Rate	20	—	200	V/µs
Gate Bias Current	—	2	10	nA

Notes:

1. Measured at +85ºC.
2. For 10 % Duty Cycle and 100 µs pulse width, measured at +85ºC.
3. Measured on non-adjacent paths, see measured data for details.
4. Measured at +25ºC.
5. Measured at 1.0 GHz and 2.0 GHz fundamental frequency and 35 dBm input power.
6. Measured at 1.0 GHz and 2.0 GHz fundamental frequency and 35 dBm input power.
7. Includes any actuator bounce, settling time to within 0.05dB of final value, and measured with 20 V/us slew rate GATE pin voltage.
8. Measured at 5 kHz cycling rate.
9. Measured with 150 V RFx to 0 V RFC.
10. Performed with 1 MΩ termination.

Hot Switch Restrictions

The MM5130 is not intended for hot switching applications and care should be taken to insure that switching occurs at less than 0.5V. These restrictions on hot switching apply to both normal mode (SP4T) and Super-Port modes of operation. If the MM5130 is used in hot switching applications, the number of cycling operations of the device will be degraded. See section Switch Reliability for more information.

Floating Node Restrictions

RF pins must not be allowed to electrically float during switch operation and therefore require some form of DC path to ground to prevent charge accumulation. DC paths can be an inductor or high value resistance which serves as a discharge path. Floating node examples and recommended solutions are:

- Unconnected RF pins, resistively terminate or tie to ground.
- Series capacitance coupling which floats RF pin, shunt with DC path to ground.
- Series connection of switches together such as in Super-Port mode without DC path to ground, shunt with DC path or sequenced switching.

See Menlo Micro application note ***Avoiding Floating Nodes*** for a detailed explanation of the hazard conditions to avoid and recommended solutions.

Thermal and Power Handling Considerations

Under normal low power operating conditions, the MM5130 case temperature mimics the environment temperature. However, during high power operation, the case will heat up due to power dissipation within the device. It is important to keep the device case temperature below 170 ºC for continued reliable operation. Based on an environmental hot temperature of 85 ºC, then an 85 ºC rise is allowable due to power dissipation. This results in a power dissipation limit of 1.13 W within the device. The operating power limit at a given frequency can then be calculated based on the device insertion loss.

Considering an insertion loss of -0.14 dB at 3000 MHz:

Power Handling = Max. Power Dissipation/(1-10^(Insertion Loss/10))

= 1.13/0.032

= 35.6 W

The MM5130 device insertion loss can also be approximated by a third order polynomial:

$$\text{Insertion Loss (dB)} = -1.1\text{E-}04 \cdot f^{3} + 1.2\text{E-}03 \cdot f^{2} – 0.024 \cdot f – 0.076$$

where f is frequency in GHz.

Alternatively, Figure 1 is provided below for the maximum power handling over frequency.

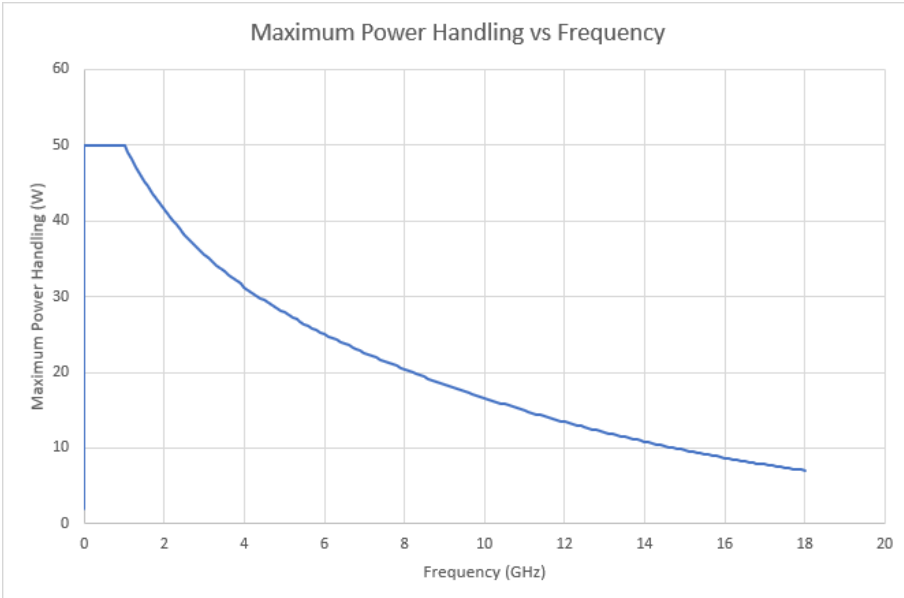


Figure 1. Maximum Power Handling vs. Frequency (1 of 2)

This approach does not hold below 5 MHz, the maximum power handling is shown in Figure 2 for frequencies below 10 MHz.

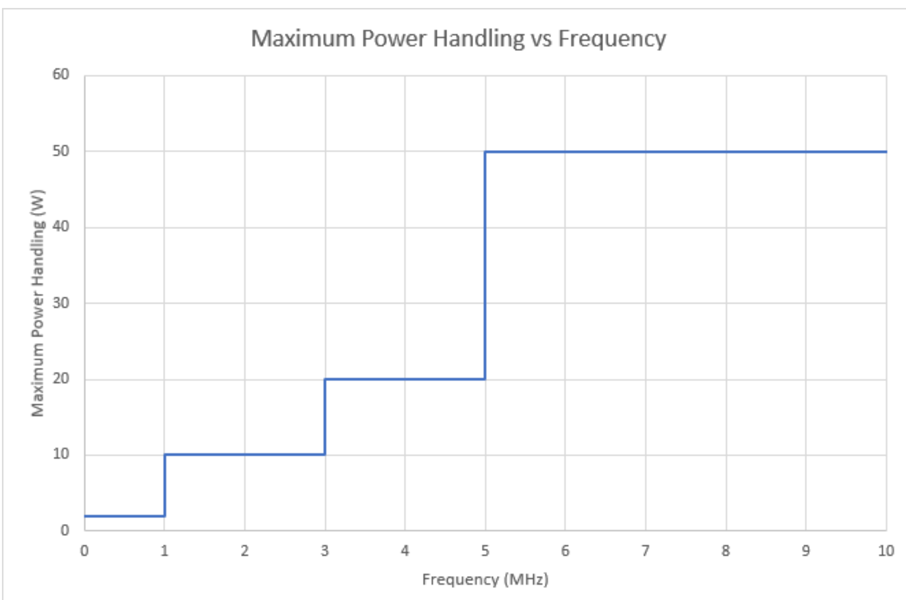


Figure 2. Maximum Power Handling vs. Frequency (2 of 2)

Functional Block Diagram

Normal SP4T Mode

The MM5130 is normally configured as a SP4T, with input on the RFC channel. The RFC is then routed to one of the 4 outputs by biasing the desired RFxGATE pin.

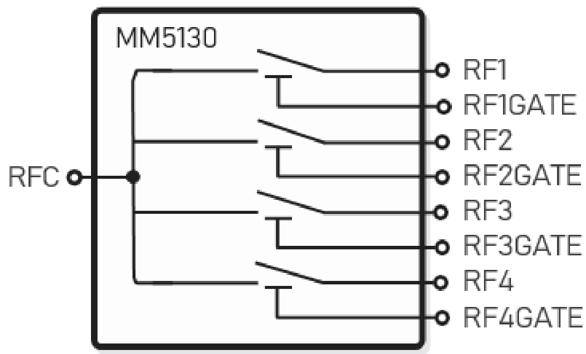


Figure 3. Normal SP4T Mode Block Diagram

Super-Port Mode

The MM5130 provides for an alternate connection method which can provide enhanced performance for certain RF parameters. This configuration is called Super-Port. It consists of bypassing the RFC input port and using the remaining 4 channels as a symmetrically oriented SP3T (or SPST or SPDT if preferred). In this manner, any one of the RF1, RF2, RF3, RF4 channels can be connected to any other channel by biasing both desired channels. When operating in Super-Port mode, slight improvements in RF isolation and return loss can be achieved. Refer to the Recommended PCB Layout section with instructions on how to optimize the PCB layout for Super-Port mode.

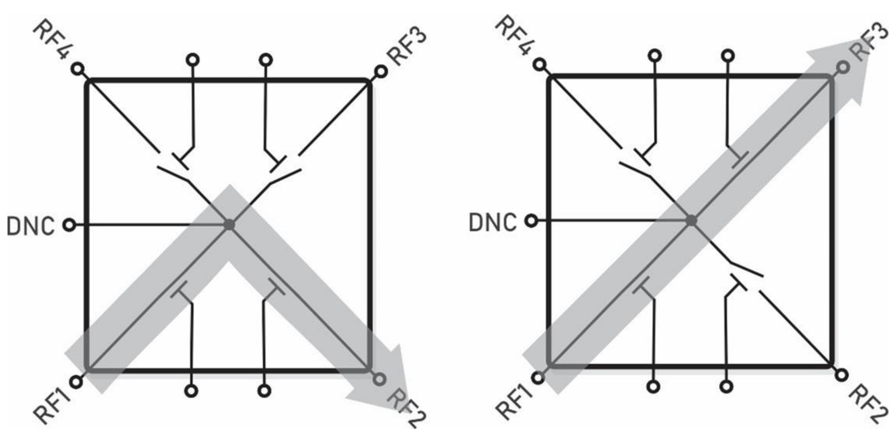


Figure 4. Super-Port Adjacent Path (Left) and Non-adjacent Path (Right)

Package / Pinout Information

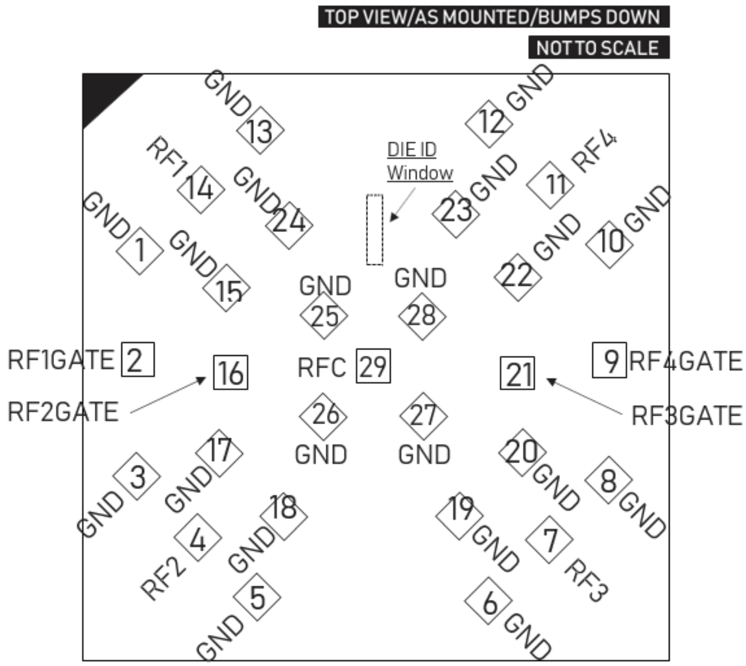


Figure 5. MM5130 2.5 mm x 2.5 mm Pinout

See Table 3 for detailed pin description.

Table 3. Detailed Pin Description

Pin Name	Pin #	Description
GND	1,3,5,6,8,10,12,13,15,17,18,19, 20,22,23,24,25,26,27,28	RF Ground
RF1GATE	2	Control for Switch RF1
RF2GATE	16	Control for Switch RF2
RF2	4	RF Switch 2
RF3	7	RF Switch 3
RF3GATE	21	Control for Switch RF3
RF4GATE	9	Control for Switch RF4
RF4	11	RF Switch 4
RF1	14	RF Switch 1
RFC	29	RF Common

Applied Gate Voltage vs. RF Switch States

Each switch is individually controllable. Primary usage states are highlighted in bold. Multiple branches may be closed simultaneously. However, RF performance is not specified for such states.

Table 4. Applied Gate Voltage vs. RF Switch States (On= Closed, Off = Open)

RF4GATE (V)	RF3GATE (V)	RF2GATE (V)	RF1GATE (V)	RFC-RF4	RFC-RF3	RFC-RF2	RFC-RF1
Normal SP4T Mode							
0	**0**	**0**	**VBB**	**Off**	**Off**	**Off**	**On**
0	**0**	**VBB**	**0**	**Off**	**Off**	**On**	**Off**
0	**VBB**	**0**	**0**	**Off**	**On**	**Off**	**Off**
VBB	**0**	**0**	**0**	**On**	**Off**	**Off**	**Off**
0	0	0	0	Off	Off	Off	Off
Other Valid States							
0	0	VBB[1]	VBB[1]	Off	Off	On	On
0	VBB[1]	0	VBB[1]	Off	On	Off	On
0	VBB[1]	VBB[1]	0	Off	On	On	Off
VBB[1]	0	0	VBB[1]	On	Off	Off	On
VBB[1]	0	VBB[1]	0	On	Off	On	Off
VBB[1]	VBB[1]	0	0	On	On	Off	Off
VBB	VBB	0	VBB	On	On	Off	On
VBB	VBB	VBB	0	On	On	On	Off
VBB	VBB	VBB	VBB	On	On	On	On
0	VBB	VBB	VBB	Off	On	On	On
VBB	0	VBB	VBB	On	Off	On	On

Notes

1. Valid states for Super-Port mode.

RF Performance

Normal Mode (SP4T)

Typical device performance measured on evaluation board, de-embedded. For band-limited applications, the performance may be further improved with narrowband matching techniques.

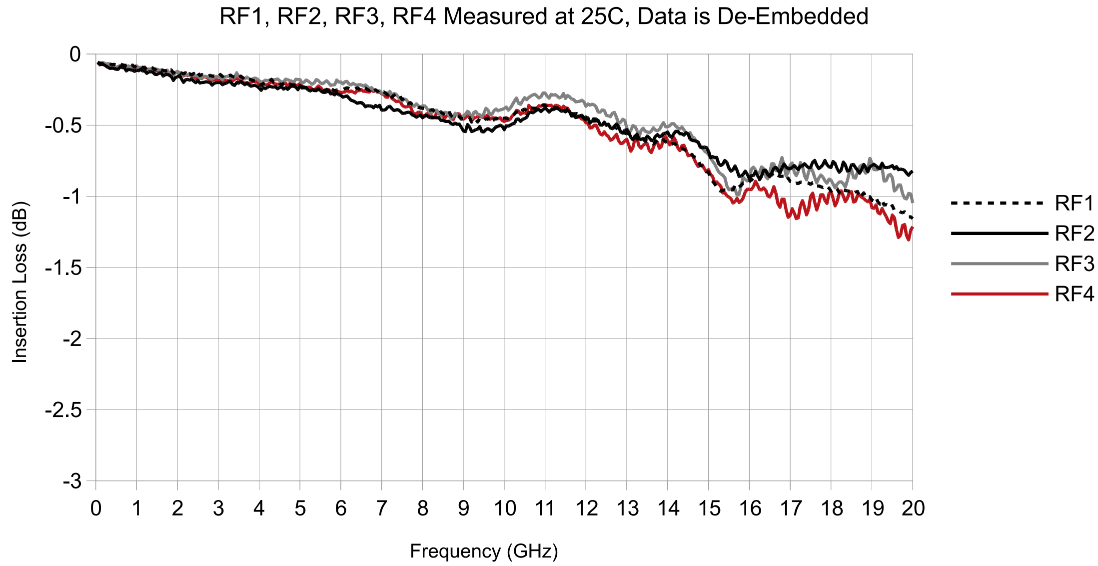


Figure 6. Insertion Loss / S21

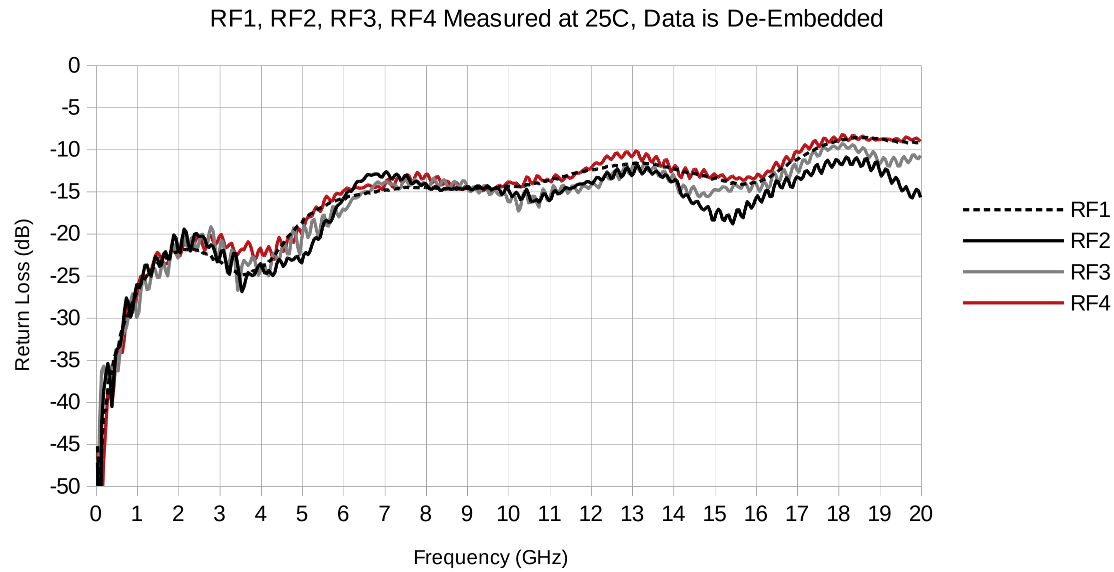


Figure 7. Return Loss / S11

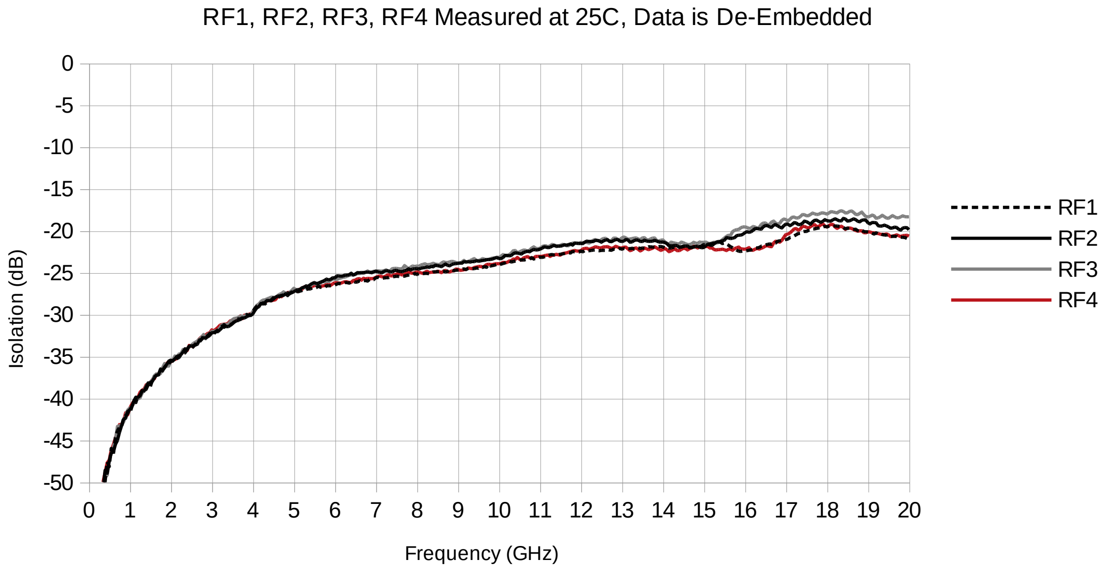


Figure 8. Off-State Isolation / S21

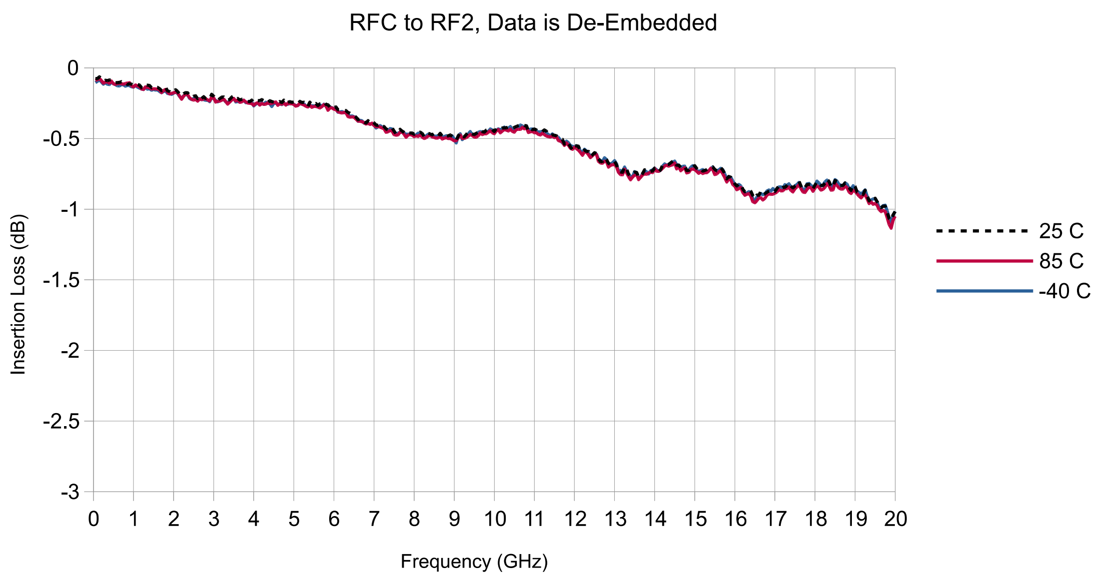


Figure 9. Insertion Loss / S21 vs. Temperature

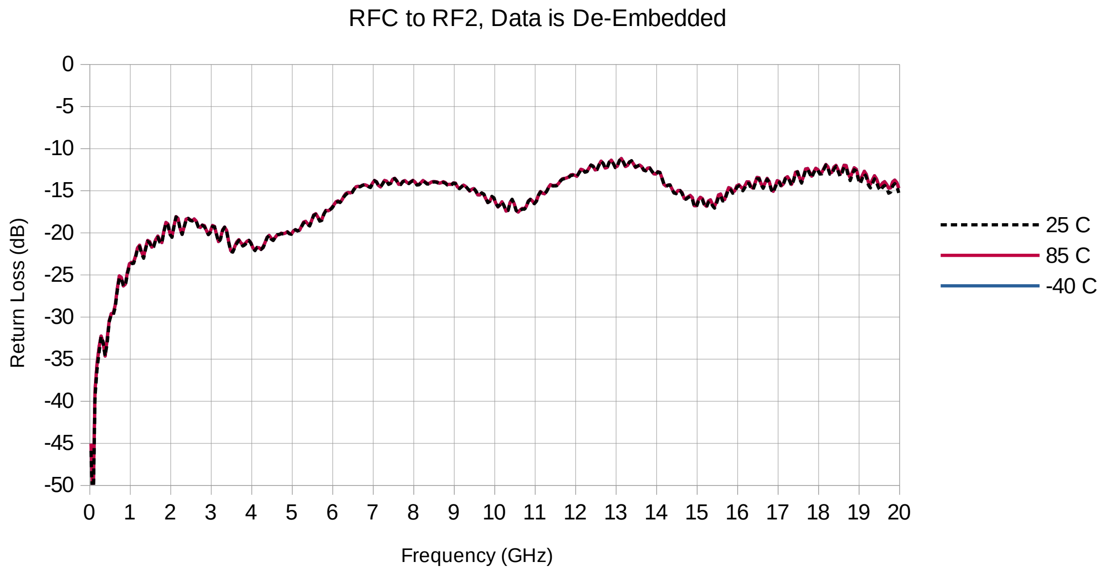


Figure 10. Return Loss / S11 vs. Temperature

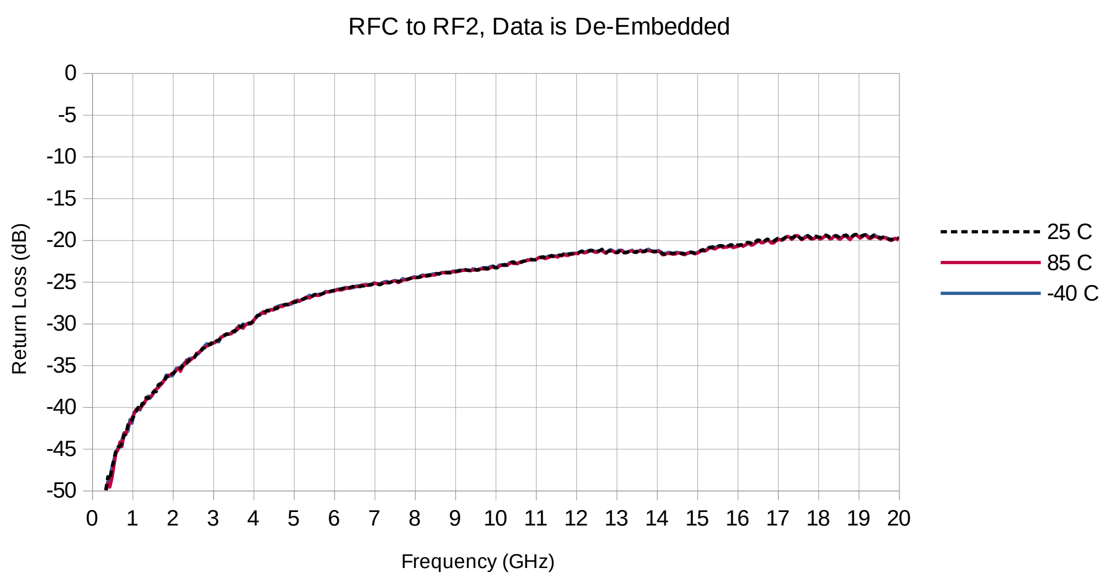


Figure 11. Off-State Isolation / S21 vs. Temperature

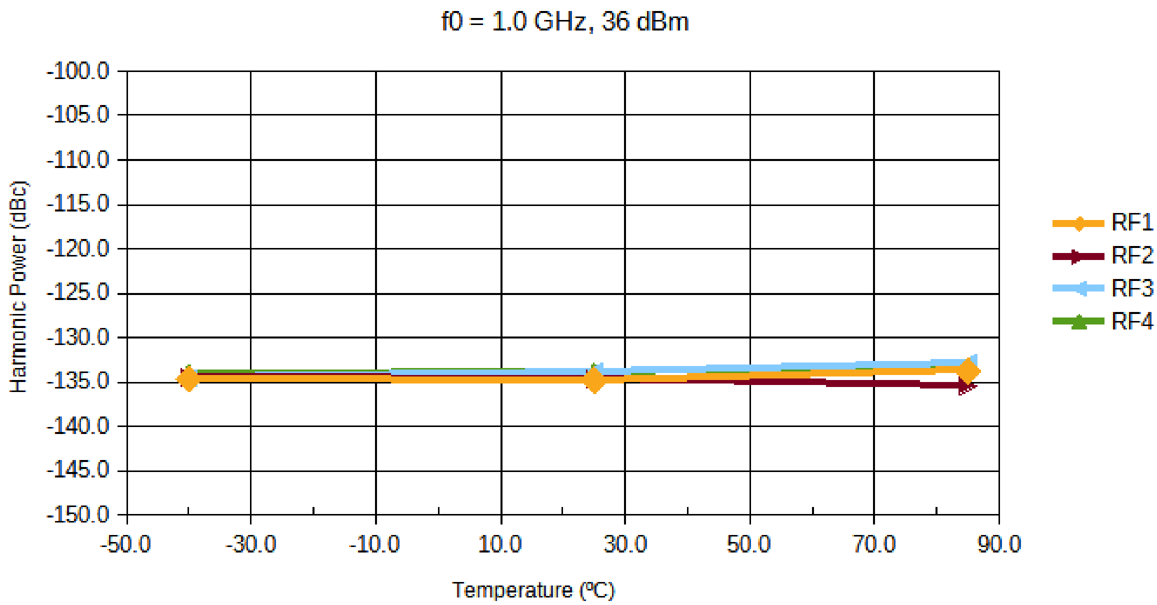


Figure 12. Second Harmonic Power vs. Temperature

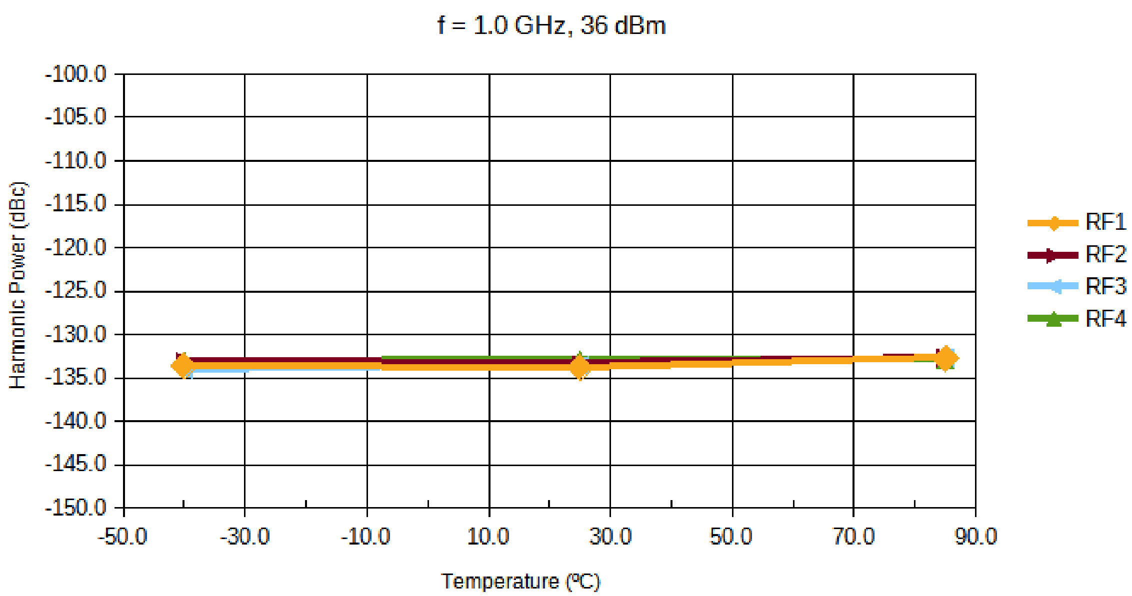


Figure 13. Third Harmonic Power vs. Temperature

On/Off Switching Time

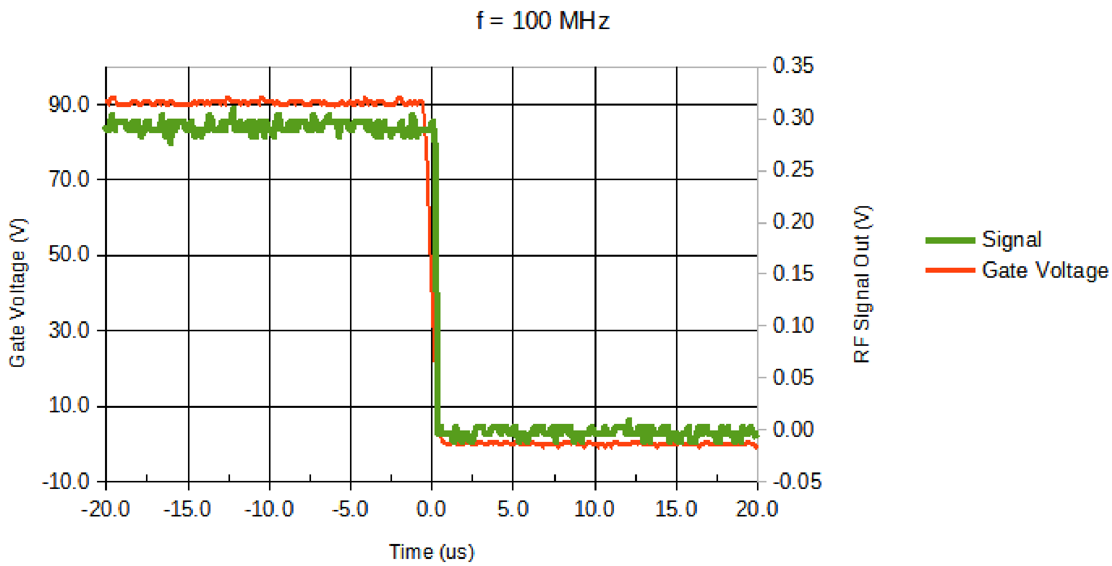


Figure 14. Switch Off Timing

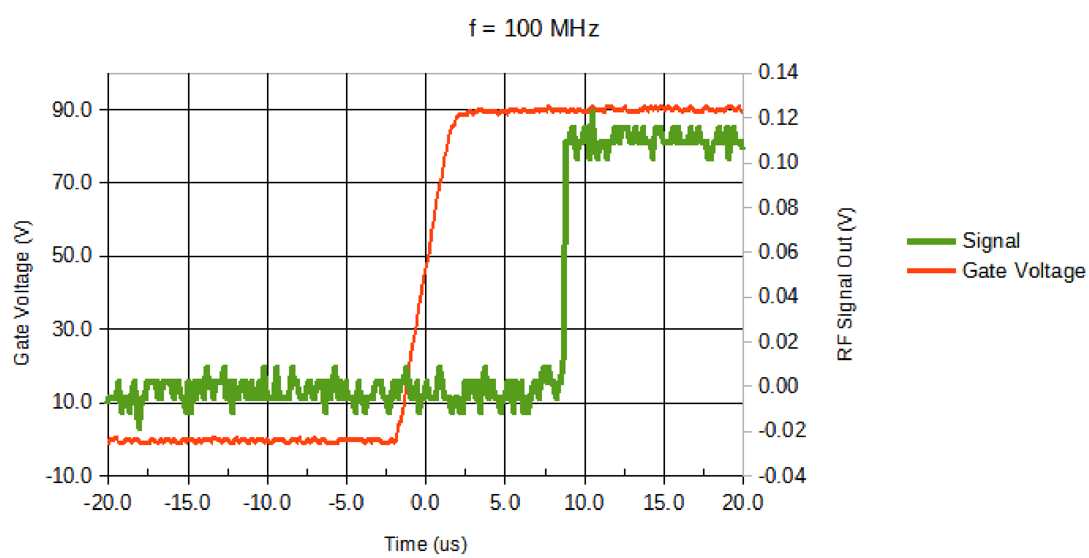


Figure 15. Switch On Timing

Single-Ended Eye Diagram Measurement

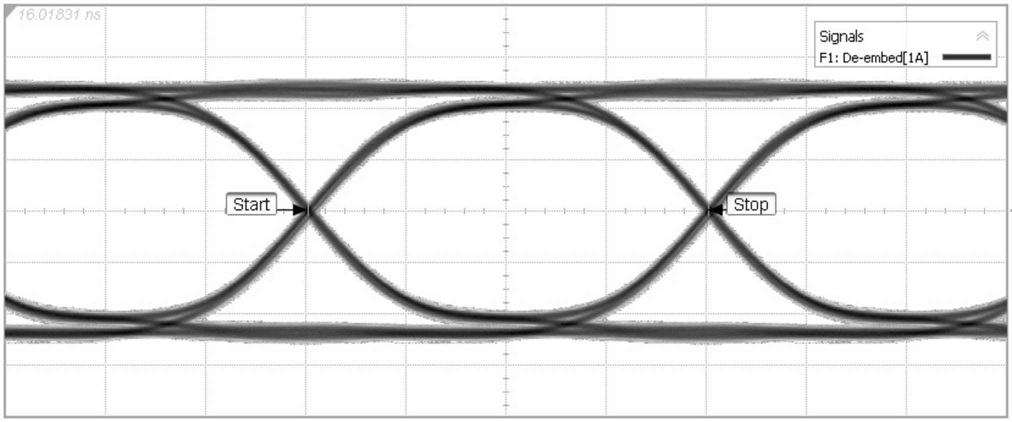


Table 5. Single-Ended Eye Diagram

Test Cases	Bit Rate	Eye Height	Eye Width	Jitter (Peak to Peak)	Rise Time	Fall Time
Baseline-Test System	20.000 Gbps	440.00 mV	48.16 ps	1.99 ps	14.99 ps	14.33 ps
MM5130 EVK	20.000 Gbps	339.80 mV	48.20 ps	2.16 ps	24.00 ps	24.34 ps

Typical Hot Switching Performance

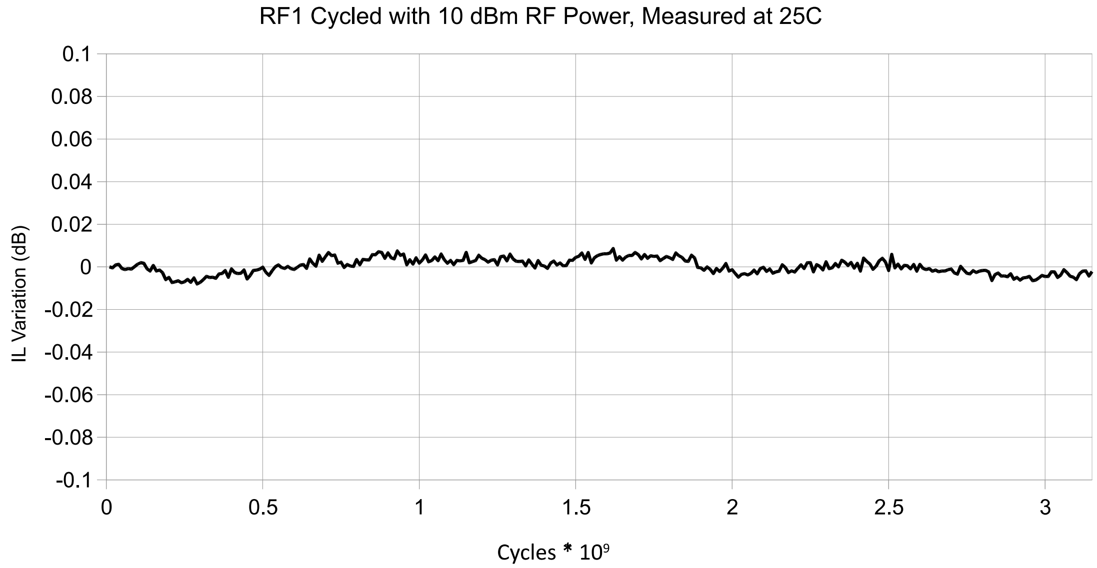


Figure 16. Insertion Loss Variation over Cycling

Super-Port Mode

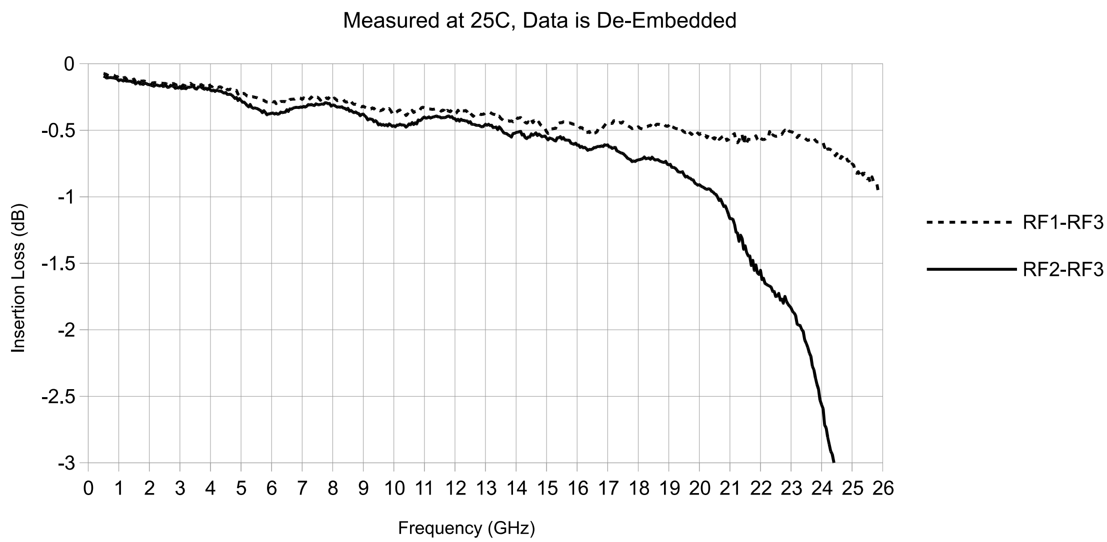


Figure 17. Super-Port Configuration Insertion Loss / S21

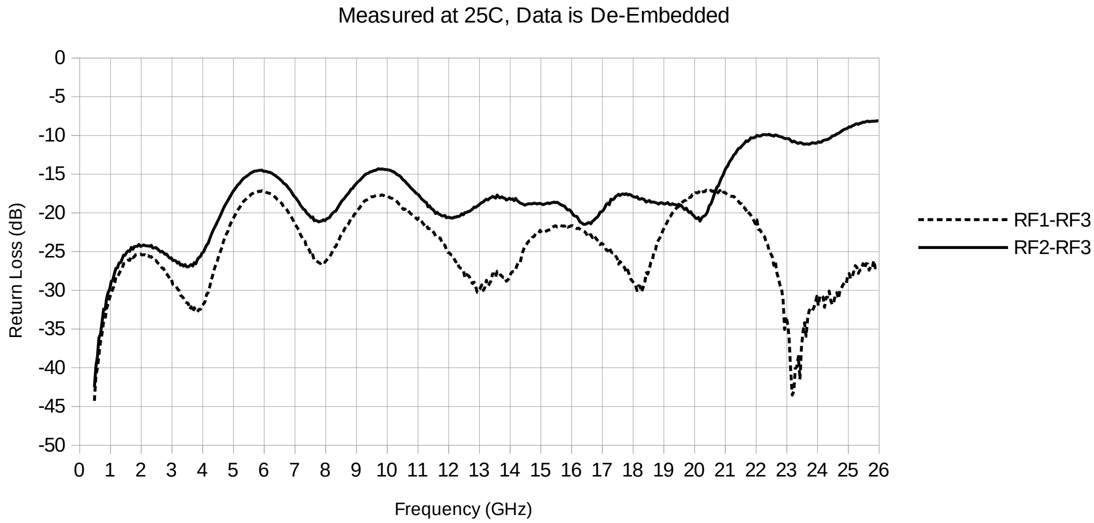


Figure 18. Super-Port Configuration Return Loss / S11

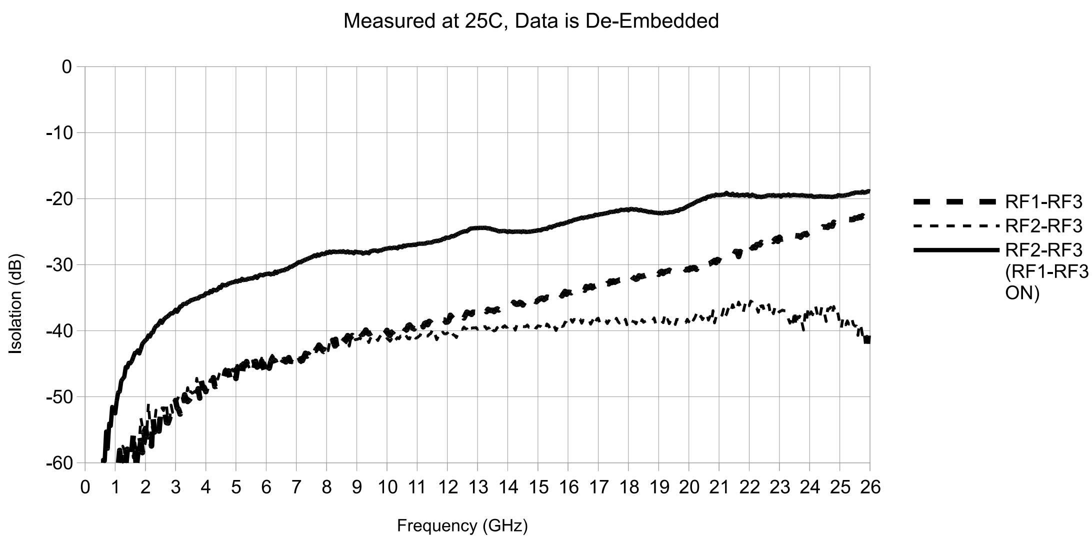


Figure 19. Super-Port Configuration Isolation / S21

Switch Reliability

Switch Hold-Down duration predictions and actuation cycling reliability test results are plotted below. Hold Down median failure is predicted to be >68000 days (>186 years) @ 50ºC and >1800 days (>4.9 years) @ 85ºC. Failure criteria is 20% change in pull in voltage and is based on creep model extrapolation of 1000 hours Hold Down test data.

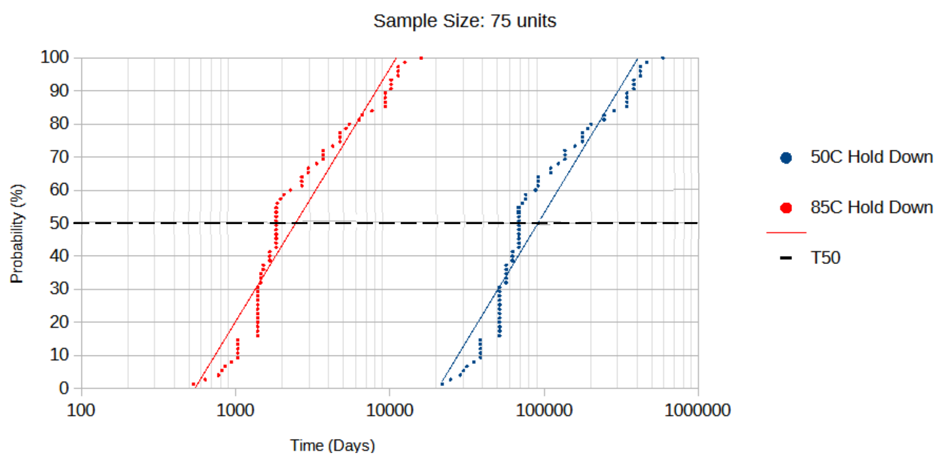


Figure 20. Hold Down: Days to Failure

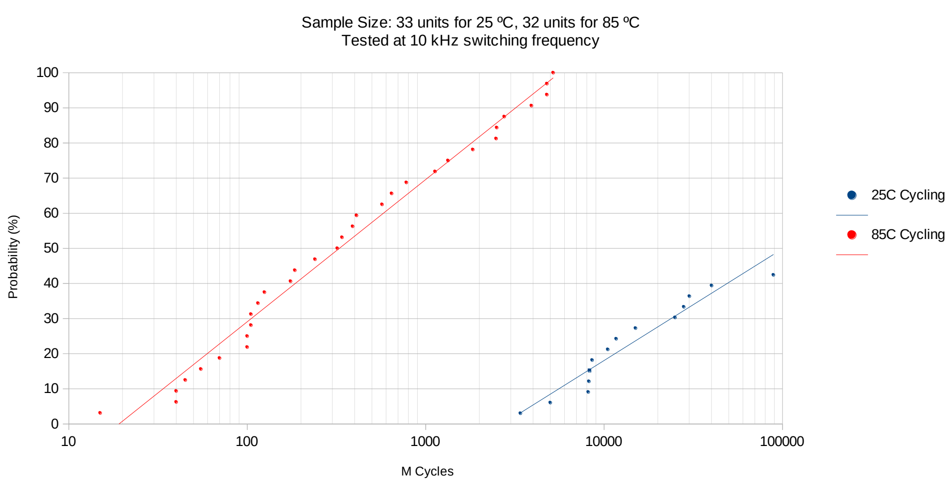


Figure 21. Cycling: M Cycles to Failure[1]

Notes:

1. Failure definition is stuck closed failure.

Hot switched actuation cycling reliability test results are plotted below from 20 dBm to 30 dBm.

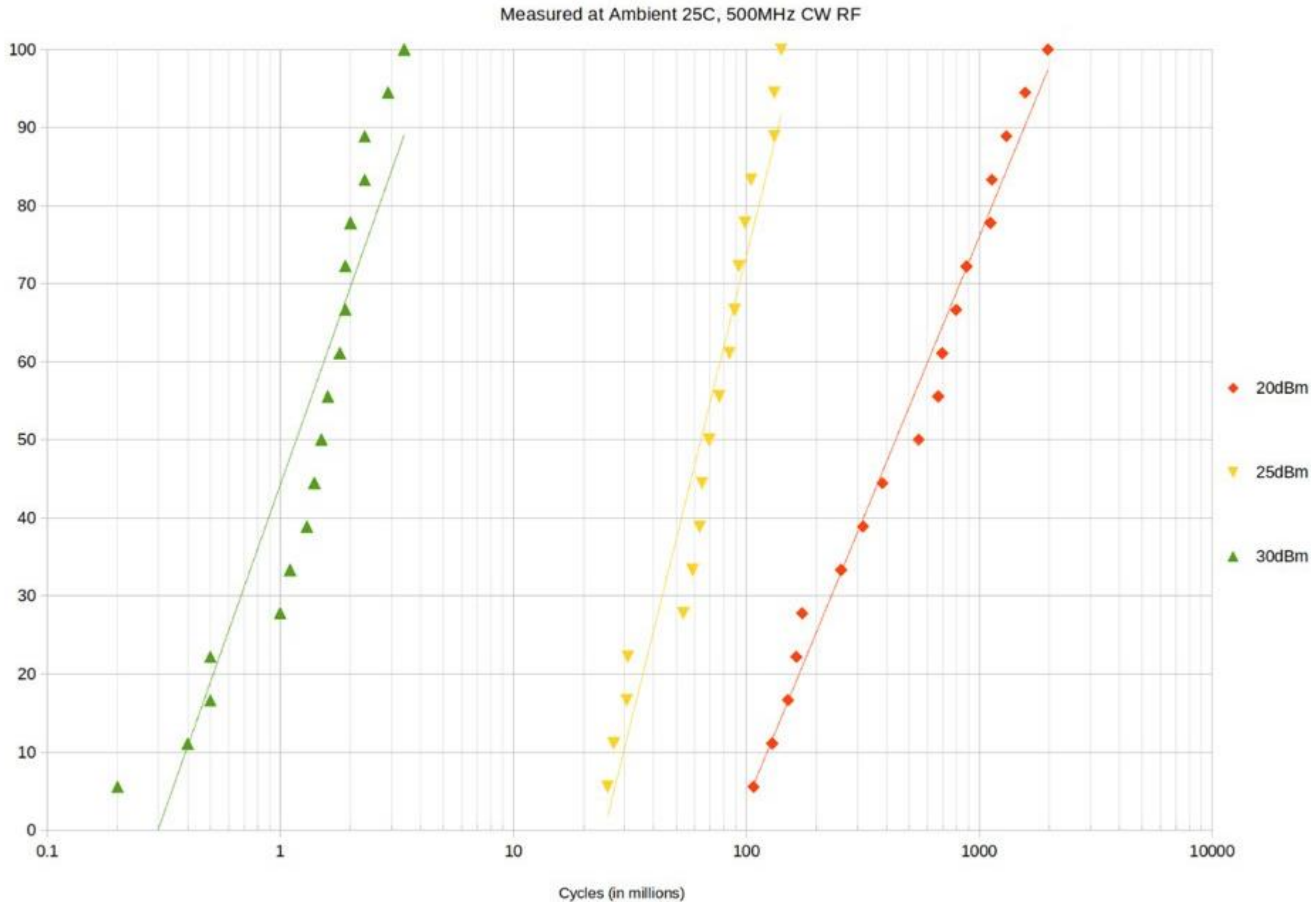
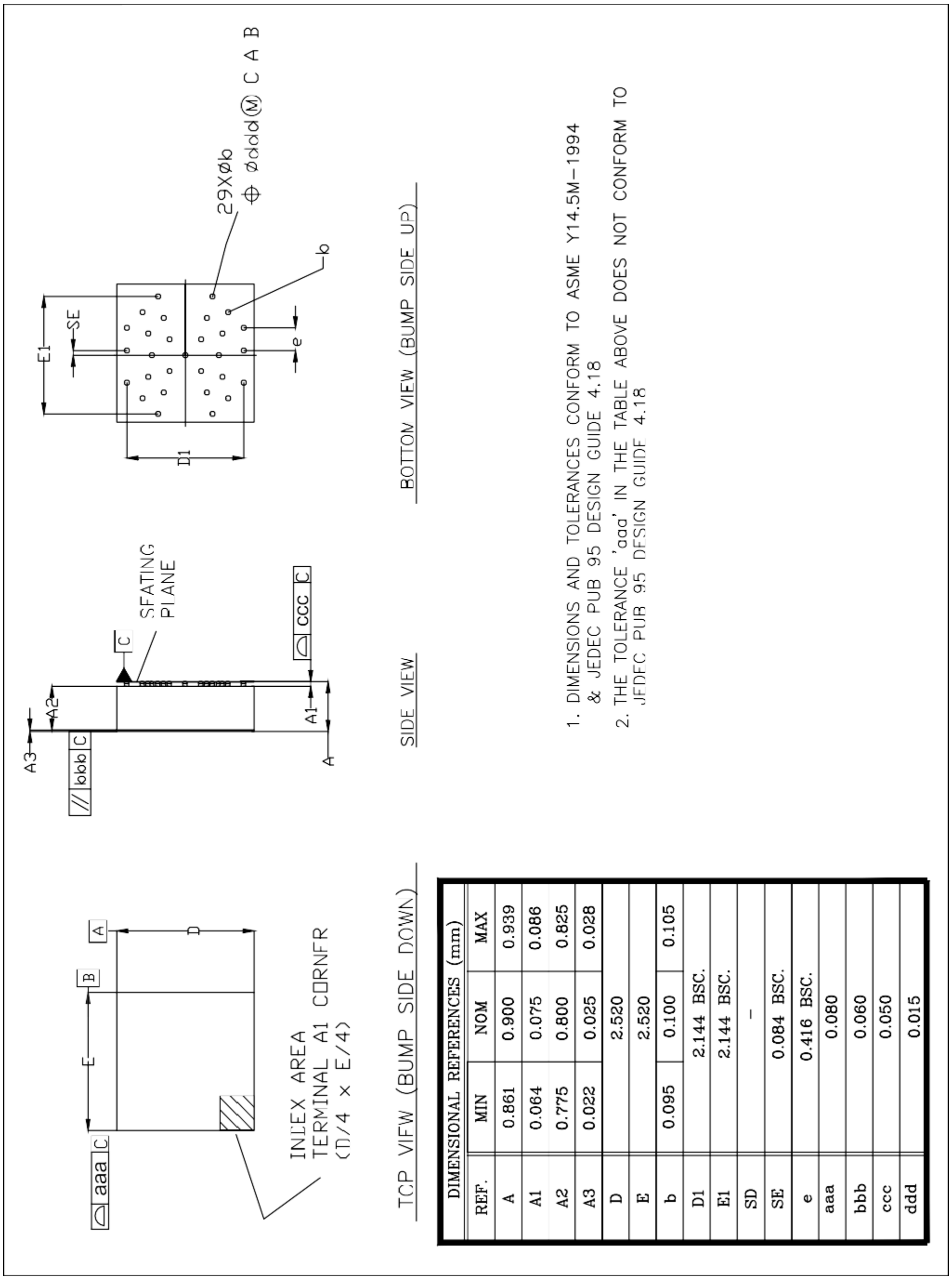


Figure 22. MM5130 Hot Switch

Package Drawing



DIMENSIONAL REFERENCES (mm)			
REF.	MIN	NOM	MAX
A	0.861	0.900	0.939
A1	0.064	0.075	0.086
A2	0.775	0.800	0.825
A3	0.022	0.025	0.028
D		2.520	
E		2.520	
b	0.095	0.100	0.105
D1		2.144 BSC.	
E1		2.144 BSC.	
SD		–	
SE		0.084 BSC.	
e		0.416 BSC.	
aaa		0.080	
bbb		0.060	
ccc		0.050	
ddd		0.015	

Figure 23. Package Drawing

Bump Coordinates

Table 6. Bump Coordinates

Pin	X (µm)	Y (µm)	Pin	X (µm)	Y (µm)	Pin	X (µm)	Y (µm)
1	1072	500	11	-786	786	21	-615	0
2	1072	84	12	-500	1072	22	-681	396
3	1072	-500	13	500	1072	23	-396	681
4	786	-786	14	786	786	24	396	681
5	500	-1072	15	681	396	25	290	290
6	-500	-1072	16	615	0	26	290	-290
7	-786	-786	17	681	-396	27	-290	-290
8	-1072	-500	18	396	-681	28	-290	290
9	-1072	84	19	-396	-681	29	0	0
10	-1072	500	20	-681	-396			

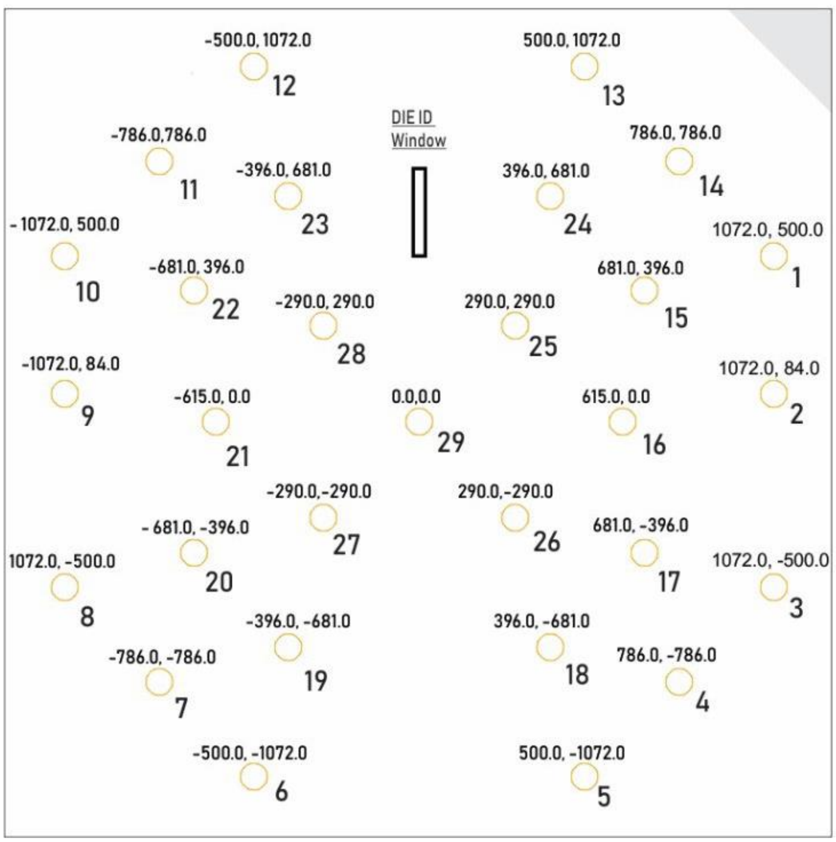


Figure 24. Bottom View/Bumps Up (0.0 at Die Center µm to Scale)

Recommended PCB Layout

Layout recommendation for connecting the MM5130 with coplanar RF line or grounded coplanar line as used for the MM5130 evaluation board. For the coplanar RF lines, it is recommended to taper the line to fit the 150µm recommended landing pad while keeping the spacing to the ground metal constant and identical to the spacing used for the line. In those two examples (Normal SP4T Mode and Super-Port Mode) a 4.0mil/0.10mm spacing is used. Recommended maximum solder resist thickness 20µm. Routing of the gate control lines is not critical for RF performance. Ensure the substrate x/y coefficient of thermal expansion (CTE) is 15 ppm/ºC or lower.

Normal SP4T Mode

Dimensions in um

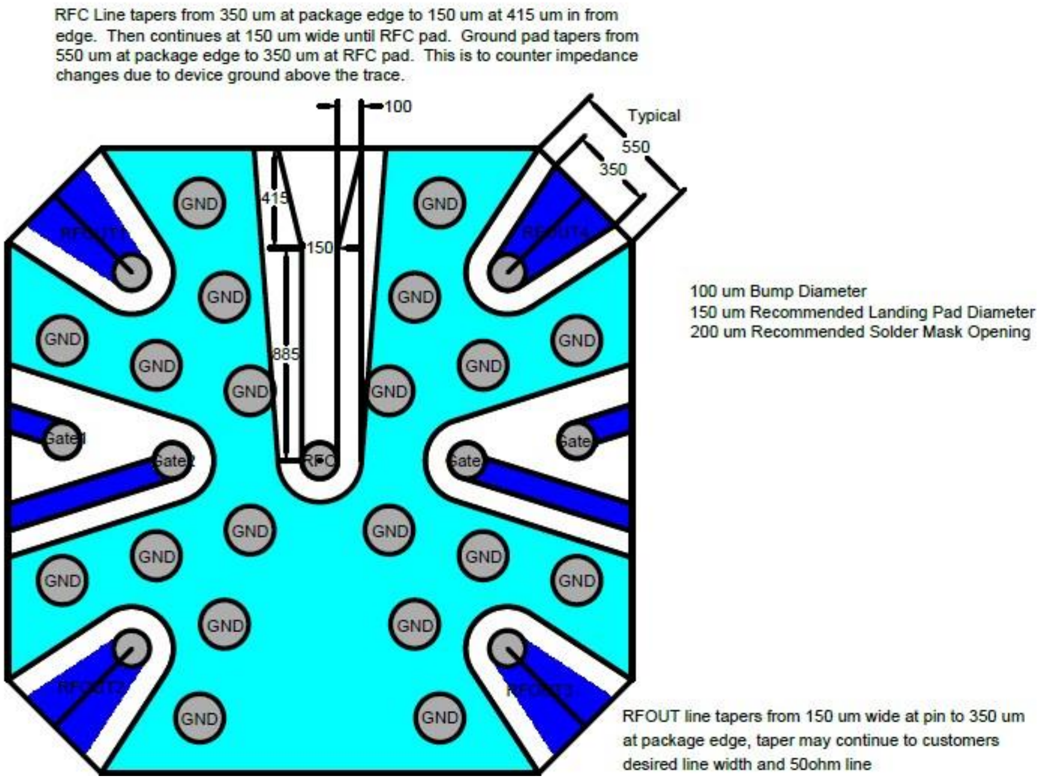


Figure 25. Normal SP4T Mode Layout Recommendation

  November 11, 2024 www.MenloMicro.com

Super-Port Mode

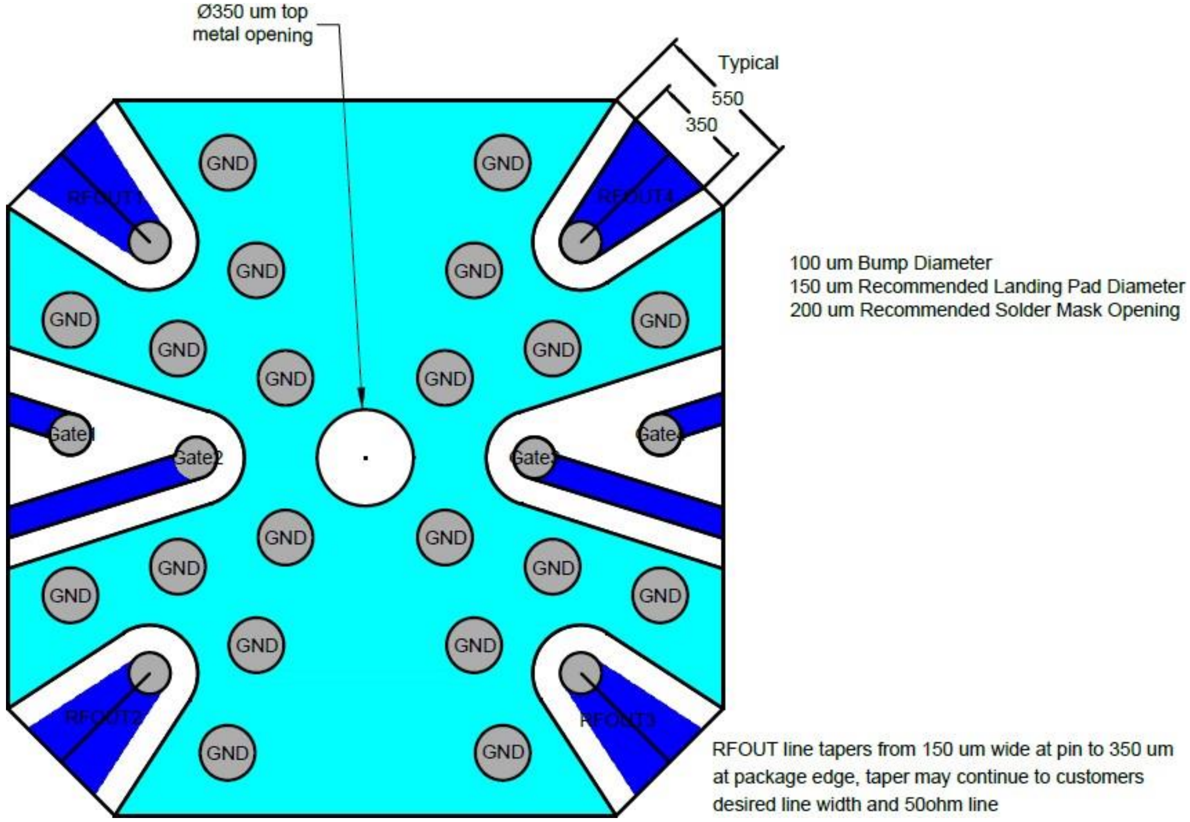


Figure 26. Super-Port Mode Layout Recommendation

Recommended Solder Reflow Profile

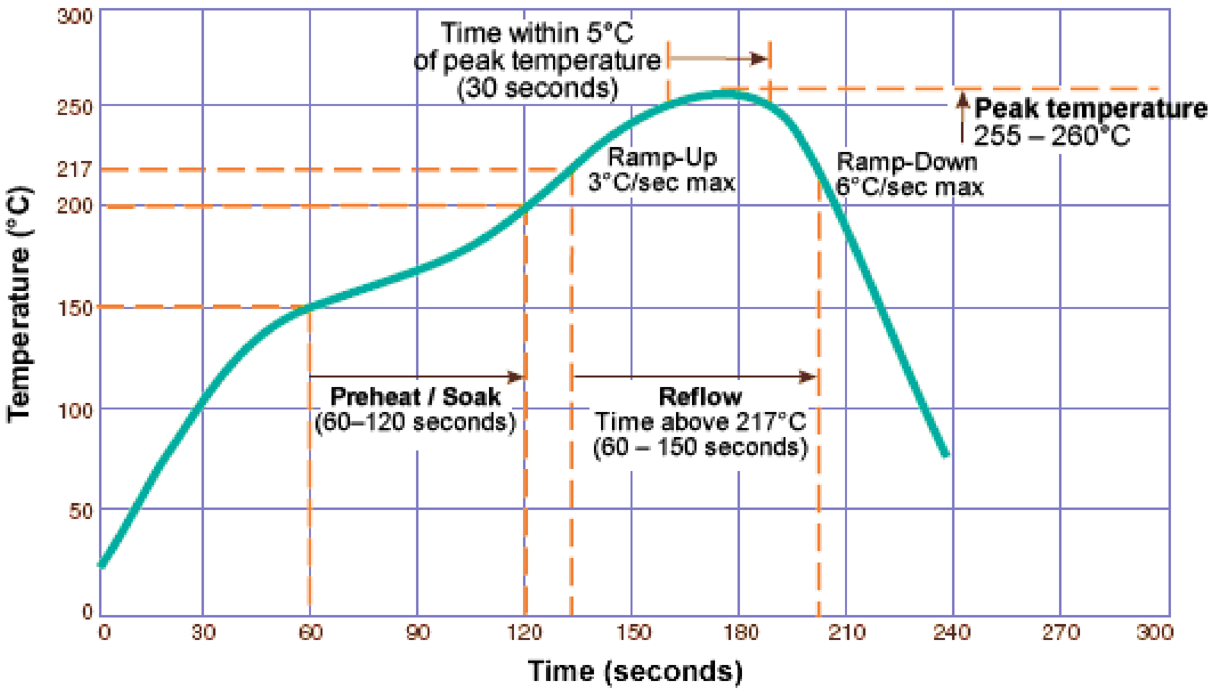


Figure 27. Reflow Profile

For detailed information on soldering the MM5130 along with SnPb soldering profile, please refer to the Menlo Micro application note *WL-FC Assembly Instructions*.

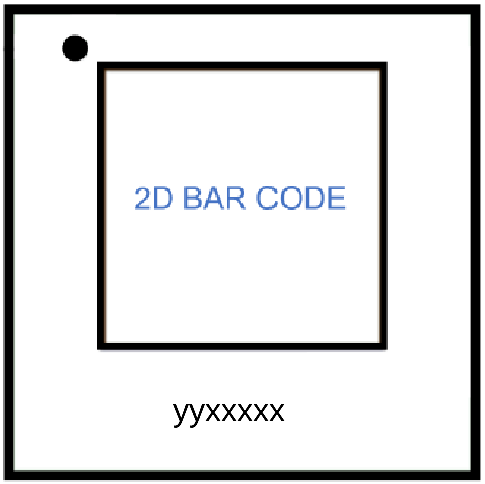
A ROHS-compliant Solder Alloy used is SAC alloy: 96.5% Sn, 3.0%Ag, 0.5%Cu. These are the nominal percentages of the components. This alloy is designed to replace SnPb solders to eliminate Lead (Pb) from the process, requiring a higher reflow temperature. Moisture resistance performance may be impacted if not using the Pb-Free reflow conditions.

Storage and Shelf Life

Under typical industry storage conditions (≤30°C/60% RH) in Moisture Barrier Bags, the following are recommended:

- Customer Shelf Life: 24 months from customer receipt date.
- Extended Shelf Life: 60 months from customer receipt date if re-bagged every 24 months or less.
- Floor life: Moisture Sensitivity Level (MSL) testing is not required for Hermetic package as per JESD47K.
- Do not re-bake.

Package Marking Information



Dot ● = Pin 1 Indicator
Line 1 = 2D Bar Code
Line 2 = Human-readable product code

Figure 28. Package Marking Drawing

Package Materials Information

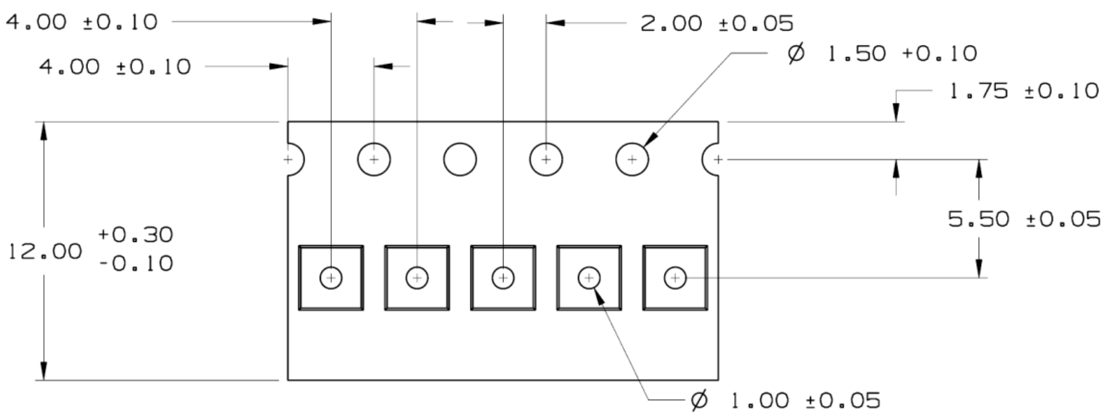


Figure 29. Tape and Reel Drawing

Package Options and Ordering Information

All Menlo Micro solutions are EAR99 compliant.

Part Number	Package Description	Temp Range	Device Marking[1]
MM5130-03NDB	DC-26GHz - SP4T 2.5 mm x 2.5 mm 29 pin WL-FC Industrial Temp	- 40ºC to +85ºC	yyxxxxx
MM5130-03NDB-TR	DC-26GHz - SP4T 2.5 mm x 2.5 mm 29 pin WL-FC Industrial Temp Tape and Reel (Qty 250)	- 40ºC to +85ºC	yyxxxxx

Notes:

1. Additional markings may be present, including logo or lot trace code information. This information may be a 2D barcode or other human-readable markings. Note that ‘x’ is a placeholder for a 5-digit numerical code and ‘yy’ is either “BB” or “BC”.

Legacy Product	New Product Name	
Name	Bulk	Tape and Reel[1]
MM5130-03C	**MM5130-03NDB**	**MM5130-03NDB-TR**

Notes:

1. 250pcs standard tape and reel increment.

Various evaluation boards are available for the MM5130 device. Please see ordering information below and in Figure 30.

Table 7. MM5130 Evaluation Boards

Part Number	EVK Description
MM5130EVK1	Standard evaluation board for MM5130 (w/SMA connector-QTY-7, <12GHz)
MM5130EVK2	High-performance evaluation board for MM5130 (w/Southwest connector- QTY-5, 18GHz improved performance)
MM5130EVK2a	High-performance evaluation board for MM5130 (w/Southwest connector- QTY-7, 18GHz improved performance)
MM5130EVK3	High-performance evaluation board for MM5130 Superport mode (w/Southwest connector-QTY-4, 26GHz improved performance)
MM5130EVK3a	High-performance evaluation board for MM5130 Superport mode (w/Southwest connector-QTY-6, 26GHz improved performance)

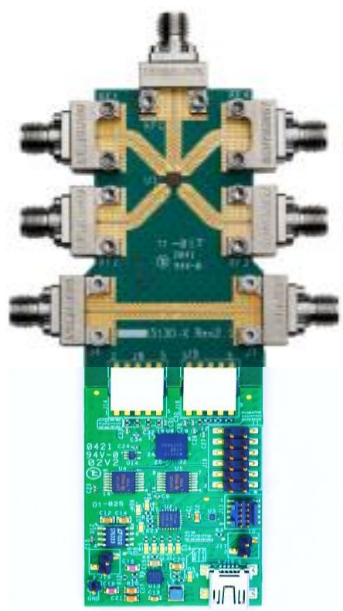


Figure 30. MM5130 EVK2a 18GHz Evaluation Board

Important Information

Disclaimer

The data presented in this document is for informational purposes only and shall in no event be regarded as a guarantee of conditions or characteristics. Any warranty or license for this product shall be specified and governed by the terms of a separate purchase agreement. Menlo Micro does not assume any liability arising out of the application or use of this product; neither does it convey any license under its patent rights, nor the rights of others.

Menlo Micro reserves the right to make changes in these specifications and features shown herein to improve reliability, function, and design; or to discontinue this product at any time without notice or obligation. Contact our product representative for the most current information.

Warning

This product is not authorized for use:

- In any life support systems.
- Applications for implanting into the human body, without the express written approval from Menlo Micro.

Trademark Notices

All trademarks and product service marks are owned by Menlo Microsystems, Inc.

Contact Information

Please contact Menlo Micro for the latest specifications, additional product information, test and evaluation boards, product samples, worldwide sales and distribution locations:

Internet: www.menlomicro.com
E-mail: sales@menlomicro.com

For product technical questions and application information: support@menlomicro.com.

